International Journal of

Rock Mechanics and Mining Sciences

Volume 32 1995

List of Contents and Author Index

Editor-in-Chief:
J. A. Hudson, Imperial College, London, UK

Pergamon

Rock Mechanics and Mining Sciences

Editor-in-Chief
Professor J. A. Hudson
7 The Quadrangle, Welwyn Garden City,
Herts AL8 6SG, U.K.

Associate Editor
Mrs C. Hudson
7 The Quadrangle, Welwyn Garden City,
Herts AL8 6SG, U.K.

Editorial Advisors
Professor E. T. Brown
Faculty of Engineering, University of Queensland, St Lucia, Queensland 4072, Australia.
Professor N. G. W. Cook
Department of Materials Science and Engineering, University of California, Hearst Mining Building, Berkeley, CA 94720, U.S.A.
Professor C. Fairhurst
Department of Civil Engineering, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., University of Minnesota, Minneapolis, MN 55455-0220, U.S.A.
Professor R. E. Goodman
Department of Civil Engineering, University of California, Davis Hall, Berkeley, CA 94720, U.S.A.
Professor E. Hoek
P.O. Box 75516, North Vancouver, Canada V7R 4X1.
Professor N. R. Morgenstern
Department of Civil Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2E1.

Editorial Board
Professor G. Barla
Department of Structural Engineering, Technical University (Politecnico) of Turin, Corso Duca degli Abruzzi 24, 10129 Torino, Italy.
Professor B. H. G. Brady
Department of Mining & Metallurgical Engineering, The University of Queensland, Brisbane, Queensland 4072, Australia.
Dr F. H. Cornet
Institut de Physique du Globe, Université Pierre et Marie Curie, 4 place Jussieu, 75230 Paris Cedex 05, France.
Professor S. L. Crouch
Department of Civil Engineering, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., University of Minnesota, Minneapolis, MN 55455-0220, U.S.A.
Professor Y. D. Diadkin
G. V. Plekhanov Mining Institute, St Petersburg V-26, 21 Liniya 2, Russia.
Professor H. K. Kutter
Ruhr-Universität Bochum, Institut für Geologie, 463 Bochum, Universitätsstrasse 150, Germany.
Dr P. R. La Pointe
Golder Associates Inc., 4104-148th Avenue N.E., Redmond, WA 98052, U.S.A.
Professor W. G. Pariseau
Department of Mining Engineering, University of Utah, 318 W. C. Browning Building, Salt Lake City, UT 84112, U.S.A.
Professor F. F. Roxborough
School of Mining Engineering, University of New South Wales, P.O. Box 1, Kensington, New South Wales 2033, Australia.
Professor K. Sassa
Department of Mining Science and Technology, Faculty of Engineering, Kyoto University, Sakyo-ku, Kyoto 606-01, Japan.
Professor O. Stephansson
Department of Engineering Geology, Royal Institute of Technology, S-100 44 Stockholm, Sweden.
Professor Qiuling Ha
President of Chinese National Group ISRM, Chief Engineer, China Three Gorges Project Development Corp., 443002 Yichang, Hubei, People's Republic of China.
Dr H. Wagner
Chamber of Mines, P.O. Box 809, Johannesburg 2000, South Africa.

Geomechanics Abstracts

Editor
S. E. Long

Consulting Editor
Dr D. H. Spencer

Editorial Director
Professor J. A. Hudson
Rock Mechanics Information Service
Imperial College of Science, Technology and Medicine
Royal School of Mines, Prince Consort Road
London SW7 2BP, U.K.
Tel. 0171-589-5111 extn 6436
Fax 0171-589-6806

Geomechanics Abstracts Database
The GeoMechanics Abstracts database (GMA), one of the many available online from the ORBIT Search Service Division of InfoPro Technologies Ltd, covers the fields of rock mechanics, soil mechanics, and engineering geology, plus the many closely related disciplines. GMA is available to the public for literature searching.

For further details please contact the ORBIT Search Service at:

North America
8000 Westpark Drive, McLean, VA 22102, U.S.A.
Tel. (800)45-ORBIT (toll free)/(703)442-0900; *Fax* (703)893-4632

Europe
Achilles House, Western Avenue, London W3 0UA, U.K.
Tel. (0181)992-3456; *Fax* (0181)993-7335

Australia
P.O. Box 544, Potts Point, NSW 2011, Australia
Tel. (02)360-2691 (direct)/(02)331-5211 (switchboard)/(008)22-6474 (toll free); *Fax* (02)332-2304

Japan
USACO Corporation, 13-12 Shinbashi 1-Chome, Minatoku, Tokyo, 105, Japan
Tel. (03)502-6471; *Fax* (03)593-2709

Copyright © 1995 Elsevier Science Ltd

Publishing office: Elsevier Science Ltd, Bampfylde Street, Exeter EX1 2AH, U.K. [*Tel.* (01392) 51558; *Fax* 425370].

Production Editor:
Bonnie Tinson (*E-mail:* b.tinson@elsevier.co.uk).

Subscription and advertising offices: Enquiries from customers in North America should be sent to Elsevier Science Inc., 660 White Plains Road, Tarrytown, NY 10591-5153, U.S.A.; and from the Rest of the World to Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, U.K. [*Tel.* Oxford (01865) 843000; *Fax* 843010].

Frequency: Published 8 issues/annum in January, February, April, June, July, September, October and December

Annual subscription rates: Annual Institutional Subscription Rates 1996: North, Central and South America, US$1249.00; Rest of the World, £785.00. Associated Personal Subscription Rates are available on request for those whose institutions are library subscribers. Sterling prices exclude VAT. Non-VAT registered customers in the European Community will be charged the appropriate VAT in addition to the price listed. Prices include postage and insurance and are subject to change without notice.

Back issues: Back issues of all previously published volumes are available direct from Elsevier Science Offices (Oxford and New York). Complete volumes and single issues can be purchased for 1990–1994. Earlier issues are available in high quality photo-duplicated copies as complete volumes only.

Second class postage paid at NEWARK, NJ. Postmaster send address corrections to *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts*, c/o Elsevier Science Inc., 660 White Plains Road, Tarrytown, NY 10591-5153, U.S.A.

CONTENTS OF VOLUME 32

NUMBER 1

Editorial
J. A. Hudson 1

A. den Outer, J. F. Kaashoek and H. R. G. K. Hack 3 Difficulties with using continuous fractal theory for discontinuity surfaces

A. J. Hyett, W. F. Bawden, G. R. Macsporran and M. Moosavi 11 A constitutive law for bond failure of fully-grouted cable bolts using a modified Hoek cell

W. Kessels and J. Kück 37 Hydraulic communication in crystalline rock between the two boreholes of the continental deep drilling project in Germany

K. J. Shou and S. L. Crouch 49 A higher order displacement discontinuity method for analysis of crack problems

International Society for Rock Mechanics. Commission on Testing Methods **R. J. Fowell (Co-ordinator)** 57 Suggested method for determining mode I fracture toughness using cracked chevron notched Brazilian disc (CCNBD) specimens

Technical Notes
A. Nowakowski and J. Nurkowski 65 A new method of measuring circumferential displacement in a triaxial cell

R. Boughrarou and D. J. Reddish 71 A study of the influence of weak viscoplastic strata in mine tunnels using finite element analysis

K. Kuriyama, Y. Mizuta, H. Mozumi and T. Watanabe 77 Three-dimensional elastic analysis by the boundary element method with analytical integrations over triangular leaf elements

L. S. Gertsch 85 Three-dimensional fracture network models from laboratory-scale rock samples

Y. Bernabé and D. T. Fryer 93 On the use of small stress excursions to investigate the mechanical behaviour of porous rocks

Geomechanics Abstracts 1A

NUMBER 2

M. Souley F. Homand and B. Amadei 101 An extension to the Saeb and Amadei constitutive model for rock joints to include cyclic loading paths

K. Kim and H. Gao 111 Probabilistic approaches to estimating variation in the mechanical properties of rock masses

J. F. Dwyer and B. Amadei 121 The edge function method and singular problems in rock mechanics

Technical Notes
S. Zhang and G. Tong 135 Influence of irregular boundary weakening on the block caving process

J. P. Harrison 143 A PostScript program for the production of equal angle equatorial hemispherical and spherical projection nets

D. P. Blair and J. J. Jiang	149	Surface vibrations due to a vertical column of explosive
M. S. King, N. A. Chaudhry and A. Shakeel	155	Experimental ultrasonic velocities and permeability for sandstones with aligned cracks
H. D. Park and M. H. de Freitas	165	The tolerances for sample preparation in the Hoop Tension Test
F. Skoczylas and J. P. Henry	171	A study of the intrinsic permeability of granite to gas
H. Yukutake and M. Shimada	181	A novel triaxial testing apparatus for deformation, fracture and frictional sliding of rocks at high pressure and temperature
Discussion		
C. A. Nóbrega and T. B. Celestino	185	Discussion of a paper by G. Li *et al.* "Fatigue crack growth in brittle sandstones"
Authors' Reply		
G. Li, K. H. R. Moelle and J. A. Lewis	187	Authors' Reply to Discussion by C. A. Nóbrega and T. B. Celestino regarding the paper "Fatigue crack growth in brittle sandstones"
Geomechanics Abstracts	45A	

NUMBER 3

B. R. Crawford, B. G. D. Smart, I. G. Main and F. Liakopoulou-Morris	189	Strength characteristics and shear acoustic anisotropy of rock core subjected to true triaxial compression
E. Pan, B. Amadei and W. Z. Savage	201	Gravitational and tectonic stresses in anisotropic rock with irregular topography
M. E. Duncan Fama, R. Trueman and M. S. Craig	215	Two- and three-dimensional elasto-plastic analysis for coal pillar design and its application to highwall mining
S. L. Huang, R. C. Speck and Z. Wang	227	The temperature effect on swelling of shales under cyclic wetting and drying
C. E. Renshaw and D. D. Pollard	237	An experimentally verified criterion for propagation across unbounded frictional interfaces in brittle, linear elastic materials
Z. Q. Wei, P. Egger and F. Descoeudres	251	Permeability predictions for jointed rock masses
Technical Notes		
C. M. Sayers	263	Stress-dependent elastic wave velocities in shales
B. G. D. Smart	269	A true triaxial cell for testing cylindrical rock specimens
E. Kuru and A. K. Wojtanowicz	277	An experimental study of sliding friction between PDC drill cutters and rocks
Geomechanics Abstracts	103A	

NUMBER 4

N. D. Cristescu and I. Paraschiv	285	The optimal shape of rectangular-like caverns

O. Z. Hekimoğlu 301 The radial line concept for cutting head pick lacing arrangements

T. Watanabe and K. Sassa 313 Velocity and amplitude of *P*-waves transmitted through fractured zones composed of multiple thin low-velocity layers

G. N. Boukharov, M. W. Chanda and N. G. Boukharov 325 The three processes of brittle crystalline rock creep

Technical Notes

F. Rummel, G. Klee and U. Weber 337 Hydraulic vs pneumatic fracturing for *in situ* stress determination in rock salt

B. Amadei, J.-F. Carlier and T. Illangasekare 343 Effect of turbulence on fracture flow and advective transport of solutes

C. Bauer, F. Homand and J. P. Henry 357 *In situ* low permeability pulse test measurements

Yangsheng Zhao, Tianhe Kang and Yaoqing Hu 365 Permeability classification of coal seams in China

M. P. Olsen, M. T. Brandon and R. B. Gordon 371 Direct measurement of volume strain during experimental deformation of porous materials

M. Cai, L. Qiao and J. Yu 375 Study and tests of techniques for increasing overcoring stress measurement accuracy

Discussion

P. R. Sheorey 385 Discussion of W. G. Pariseau's Technical Note "On the significance of dimensionless failure criteria"

Geomechanics Abstracts 149A

NUMBER 5

THERMO-HYDRO-MECHANICAL COUPLING IN ROCK MECHANICS

Introduction

O. Stephansson 387

L. Jing, C.-F. Tsang and O. Stephansson 389 DECOVALEX—an international co-operative research project on mathematical models of coupled THM processes for safety analysis of radioactive waste repositories

A. Makurat, M. Ahola, K. Khair, J. Noorishad, L. Rosengren and J. Rutqvist 399 The DECOVALEX test—case one

A. Millard, M. Durin, A. Stietel, A. Thoraval, E. Vuillod, H. Baroudi, F. Plas, A. Bougnoux, G. Vouille, A. Kobayashi, K. Hara, T. Fujita and Y. Ohnishi 409 Discrete and continuum approaches to simulate the thermo-hydro-mechanical couplings in a large, fractured rock mass

T. Chan, K. Khair, L. Jing, M. Ahola, J. Noorishad and E. Vuillod 435 International comparison of coupled thermo-hydro-mechanical models of a multiple-fracture bench mark problem: DECOVALEX Phase I, bench mark test 2

G. Rehbinder	453	Analytical solutions of stationary coupled thermo-hydro-mechanical problems
T. S. Nguyen and A. P. S. Selvadurai	465	Coupled thermal-mechanical-hydrological behaviour of sparsely fractured rock: implications for nuclear fuel waste disposal
G. Abdallah, A. Thoraval, A. Sfeir and J. P. Piguet	481	Thermal convection of fluid in fractured media
Y. Jiao and J. A. Hudson	491	The fully-coupled model for rock engineering systems
Technical Notes		
J. Rutqvist	513	Determination of hydraulic normal stiffness of fractures in hard rock from well testing
J. Claesson, S. Follin, G. Hellström and N.-O. Wallin	525	On the use of the diffusion equation in test case 6 of DECOVALEX
P. W. H. Olden, M. Jin, B. G. D. Smart and A. D. H. Tehrani	529	Rock mechanics factors in enhanced fluid flow simulation
Geomechanics Abstracts	201A	

NUMBER 6

D. D. Tannant, R. K. Brummer and X. Yi	537	Rockbolt behaviour under dynamic loading: field tests and modelling
G. E. Exadaktylos and C. E. Tsoutrelis	551	Pillar failure by axial splitting in brittle rocks
A. Zang and T.-F. Wong	563	Elastic stiffness and stress concentration in cemented granular material
M. Mauldon	575	Keyblock probabilities and size distributions: a first model for impersistent 2-D fractures
U. K. Singh, P. N. Jain and M. Prasad	585	Post–pillar behaviour at deep levels in a copper mine
A. M. Ferrero	595	The shear strength of reinforced rock joints
A. Kijko and M. Sciocatti	607	Optimal spatial distribution of seismic stations in mines
Technical Notes		
S. T. Quek and C. F. Leung	617	Reliability-based stability analysis of rock excavations
B. S. Aadnoy and F. Angell-Olsen	621	Some effects of ellipticity on the fracturing and collapse behavior of a borehole
A. M. Milev, S. M. Spottiswoode and K. R. Noble	629	Mine-induced seismicity at East Rand Proprietary Mines
Geomechanics Abstracts	251A	

NUMBER 7

B. Benmokrane, A. Chennouf and H. S. Mitri	633	Laboratory evaluation of cement-based grouts and grouted rock anchors

F. E. Heuze, R. P. Swift, L. R. Hill and W. H. Barrett 643 Behavior of a steel liner-and-bolts system under very high thermal and mechanical loading

P. H. S. W. Kulatilake, G. Shou, T. H. Huang and R. M. Morgan 673 New peak shear strength criteria for anisotropic rock joints

P. R. Sheorey, D. Barat, K. P. Mukherjee, R. K. Prasad, M. N. Das, G. Banerjee and K. K. Das 699 Application of the yield pillar technique for successful depillaring under stiff strata

A. Azzoni, G. La Barbera and A. Zaninetti 709 Analysis and prediction of rockfalls using a mathematical model

Technical Notes

M. Yumlu and M. U. Ozbay 725 A study of the behaviour of brittle rocks under plane strain and triaxial loading conditions

M. Cai, L. Qiao, C. Li, J. Yu, B. Yu and G. Chen 735 Application of an improved hollow inclusion technique for *in situ* stress measurement in Xincheng Gold Mine, China

Geomechanics Abstracts 303A

NUMBER 8

I. L. Meglis, T. M. Chow and R. P. Young 741 Progressive microcrack development in tests on Lac du Bonnet granite—I. Acoustic emission source location and velocity measurements

T. M. Chow, I. L. Meglis and R. P. Young 751 Progressive microcrack development in tests on Lac du Bonnet granite—II. Ultrasonic tomographic imaging

Technical Note

L. L. Mishnaevsky Jr 763 Physical mechanisms of hard rock fragmentation under mechanical loading: a review

Geomechanics Abstracts 357A

AUTHOR INDEX

Aadnoy B. S., 621
Abdallah G., 481
Ahola M., 399, 435
Amadei B., 101, 121, 201, 343
Angell-Olsen F., 621
Azzoni A., 709

Banerjee G., 699
Barat D., 699
Baroudi H., 409
Barrett W. H., 643
Bauer C., 357
Bawden W. F., 11
Benmokrane B., 633
Bernabé Y., 93
Blair D. P., 149
Boughrarou R., 71
Bougnoux A., 409
Boukharov G. N., 325
Boukharov N. G., 325
Brandon M. T., 371
Brummer R. K., 537

Cai M., 375, 735
Carlier J.-F., 343
Celestino T. B., 185
Chan T., 435
Chanda M. W., 325
Chaudhry N. A., 155
Chen G., 735
Chennouf A., 633
Chow T. M., 741, 751
Claesson J., 525
Craig M. S., 215
Crawford B. R., 189
Cristescu N. D., 285
Crouch S. L., 49

Das K. K., 699
Das M. N., 699
Descoeudres F., 251
Durin M., 409
Dwyer J. F., 121

Egger P., 251
Exadaktylos G. E., 551

Fama M. E. D., 215
Ferrero A. M., 595
Follin S., 525
Fowell R. J., 57
de Freitas M. H., 165
Fryer D. T., 93
Fujita T., 409

Gao H., 111
Gertsch L. S., 85
Gordon R. B., 371

Hack H. R. G. K., 3
Hara K., 409
Harrison J. P., 143
Hekimoğlu O. Z., 301
Hellström G., 525
Henry J. P., 171, 357
Heuze F. E., 643
Hill L. R., 643
Homand F., 357
Homand M. S. F., 101
Huang S. L., 227
Huang T. H., 673
Hudson J. A., 1, 491
Hyett A. J., 11

Illangasekare T., 343

Jain P. N., 585
Jiang J. J., 149
Jiao Y., 491
Jin M., 529
Jing L., 389, 435

Kaashoek J. F., 3
Kessels W., 37
Khair K., 399, 435
Kijko A., 607
Kim K., 111
King M. S., 155
Klee G., 337
Kobayashi A., 409
Kulatilake P. H. S. W., 673
Kuriyama K., 77
Kuru E., 277
Kück J., 37

La Barbera G., 709
Leung C. F., 617
Lewis J. A., 187
Li C., 735
Li G., 187
Liakopoulou-Morris F., 189

Macsporran G. R., 11
Main I. G., 189
Makurat A., 399
Mauldon M., 575
Meglis I. L., 741, 751
Milev A. M., 629
Millard A., 409
Mishnaevsky L. L. Jr, 763
Mitri H. S., 633
Mizuta Y., 77
Moelle K. H. R., 187
Moosavi M., 11
Morgan R. M., 673
Mozumi H., 77
Mukherjee K. P., 699

Nguyen T. S., 465
Noble K. R., 629
Noorishad J., 399, 435
Nowakowski A., 65
Nóbrega C. A., 185
Nurkowski J., 65

Ohnishi Y., 409
Olden P. W. H., 529
Olsen M. P., 371
den Outer A., 3
Ozbay M. U., 725

Pan E., 201
Paraschiv I., 285
Park H. D., 165
Piguet J. P., 481
Plas F., 409
Pollard D. D., 237
Prasad M., 585
Prasad R. K., 699

Qiao L., 375, 735
Quek S. T., 617

Reddish D. J., 71
Rehbinder G., 453
Renshaw C. E., 237
Rosengren L., 399
Rummel F., 337
Rutqvist J., 399, 513

Sassa K., 313
Savage W. Z., 201
Sayers C. M., 263
Sciocatti M., 607
Selvadurai A. P. S., 465
Sfeir A., 481
Shakeel A., 155
Sheorey P. R., 385, 699
Shimada M., 181
Shou G., 673
Shou K. J., 49
Singh U. K., 585
Skoczylas F., 171
Smart B. G. D., 189, 269, 529
Speck R. C., 227
Spottiswoode S. M., 629
Stephansson O., 387, 389
Stietel A., 409
Swift R. P., 643

Tannant D. D., 537
Tehrani A. D. H., 529
Thoraval A., 409, 481
Tianhe Kang, 365
Tong G., 135
Trueman R., 215
Tsang C.-F., 389
Tsoutrelis C. E., 551

Vouille G., 409
Vuillod E., 409, 435

Wallin N.-O., 525
Wang Z., 227
Watanabe T., 77, 313
Weber U., 337
Wei Z. Q., 251
Wojtanowicz A. K., 277
Wong T.-F., 563

Yangsheng Zhao, 365
Yaoqing Hu, 365
Yi X., 537
Young R. P., 741, 751
Yu B., 735
Yu J., 375, 735
Yukutake H., 181
Yumlu M., 725

Zang A., 563
Zaninetti A., 709
Zhang S., 135

Typeset in Great Britain by BPC Digital Techset Ltd, Exeter. Printed by BPC Wheatons Ltd, Exeter